Assignment Discovery Online Curriculum

Lesson title:
Stable and Unstable Structures

Grade level:
6-8

Subject area:
Technology and Physical Science

Duration:
One to two class periods

Objectives:
Students will
1. examine the structural flaws that caused three bridges to collapse,
2. determine what factors need to be considered in building a stable structure, and
3. compare and contrast the pros and cons of various bridge building materials.

Materials:

The class will need the following:
- Computers with Internet access (optional but very helpful)

Each student will need the following:
- Paper
- Pencils and pens
- One copy of Classroom Activity Sheet: Designing Bridges
- One copy of the Structures Fact Sheet (Distribute this to students if they don't have access to the Internet and need the information in order to complete the activity.)
- One copy of Take-Home Sheet**:** Top 10 Construction Achievements of the 20th Century

This lesson plan can be enhanced by purchasing and viewing the documentary *Collapse: Failure by Design* from our School Store. The documentary airs on the Discovery Channel February 16, March 23, April 27, and June 1, 2001.

Procedures:

1. Begin the discussion by showing the class two photographs of the Tacoma-Narrows Bridge, in the state of Washington, in the process of collapsing. You can find these images at the following Web sites:
   Photo 1: http://www.pbs.org/wgbh/buildingbig/wonder/structure/narrows1_bridge.html

Photo 2: http://www.pbs.org/wgbh/buildingbig/wonder/structure/narrows2_bridge.html

2. Ask students to brainstorm about the causes that forced this bridge to wobble and then fall apart. (You may want to ask them if certain weather conditions may have contributed to the bridge's collapse.) Write their suggestions on a piece of newsprint. After discussing students' ideas, explain that the cause of the collapse was winds of more than 40 miles per hour.

3. Discuss with the class two other bridges that have collapsed:

   - Silver Bridge, Point Pleasant, West Virginia, 1967. In the worst bridge disaster in the history of the United States, 37 trucks and cars fell into the water when this bridge collapsed. The damage was caused by a broken I-bar, a small metal beam that connects the bridge's different parts. As engineers found out later, one I-bar had a tiny crack at the time of construction; over time the wear and tear of weather and traffic broke the I-bar apart. Once one side of the bridge fell, the other side couldn't handle the weight, so it collapsed too.
   - Melbourne Bridge, Melbourne, Australia, 1968. When constructing the bridge, engineers and architects made a simple mathematical error that resulted in an instability in the bridge's steel girder box. When some of the steel expanded from heat, the bridge fell 120 feet to the ground.

4. Using the information about bridge collapses as a starting point for discussion, ask students what variables must be considered when building a bridge. Point out that these include environmental factors, such as wind and temperature, building materials, and shapes used to support the structure. Also, discuss with the class the natural forces with which structures must contend, such as the weight of a building pressing down on the lower columns (compression) and natural stretching of materials (tension). Explain how these factors also must be taken into consideration when designing a bridge.

5. Divide the class into small groups of three or four students. Tell each group to design a plan, or blueprint, for a bridge to cross a gap in your city or town; the bridge could cross a river or join two sections of land. Their goal is to propose the strongest, safest bridge they can with the least expensive materials. As students work, have them answer the questions listed below and record their findings on the Classroom Activity Sheet: Designing a Bridge.

- What natural forces might affect your bridge? How can you compensate for them?
- What materials are most suitable for your bridge? Keep in mind wear and tear on the bridge, temperature, wind speed, and expense when making your decision.
- How much weight can triangles, rectangles, and arches support? Which is most suitable for your bridge? Why?

To guide students in their research, you may want to distribute copies of the Structures Fact Sheet, which provides information on common forces (such as tension and compression), properties of different materials (such as steel and concrete), and how shapes (such as rectangles and arches) affect designs. To conduct the necessary research, have students visit the Web sites listed below.

Forces Lab: squeezing, stretching, bending, sliding
http://www.pbs.org/wgbh/buildingbig/lab/forces.html

Materials Lab: wood, plastic, aluminum, brick, concrete, reinforced concrete, cast iron, steel
http://www.pbs.org/wgbh/buildingbig/lab/materials.html

Shapes Lab: rectangles, arches, triangles
http://www.pbs.org/wgbh/buildingbig/lab/shapes.html

6. Have the groups write down their recommendations and draw their blueprints on the Classroom Activity Sheet: Designing a Bridge. Suggest that each student make a copy of his or her group's recommendations. Then have the groups present their designs to the class. Give other students a chance to comment on the strengths and weaknesses of each design.

7. Assign the Take-Home Sheet**:** Top 10 Construction Achievements of the 20th Century for homework. Students will research one of the structures honored by the architectural community in 1999. They will record important facts about the structure and find out how it is reinforced to protect against destructive forces such as high winds, floods, and earthquakes. After students complete the assignment, have them share their findings with the class.

Adaptation for older students:
Students in high school could take this assignment one step further by creating 3-D models of their proposed bridges. Alternatively, they could simulate a famous bridge disaster by first building a small, inexpensive model of a bridge that collapsed, then replicating the forces that caused its collapse. For example, high winds can be simulated using a fan, and an earthquake can be simulated by shaking the table supporting the model. The following Web site on bridge disasters might be helpful in completing this project:
http://www.iti.nwu.edu/clear/bridge/bri_dis.html

Questions:
1. What are some of the forces that could cause a bridge to collapse?
2. What are the differences between concrete and reinforced concrete?
3. Which of the following shapes would be best able to handle pressure from the top: horizontal rectangle, arch, or triangle? Why? Which would be the weakest?
4. If you were developing a list of safety measure for bridges, what items would you include on your list? Why?
5. In addition to the bridges discussed in this lesson, can you name some other structures, such as dams, tunnels, or buildings, that have collapsed? Why did these structures collapse?

6. In 1979, the Kemper Arena in Kansas City, Mo., was hit with severe thunderstorms. Because of its poor drainage systems, the roof filled with water. Why do you think this caused the building to cave in?

Evaluation:

Students should be able to work well together, complete the research accurately and thoroughly, develop a reasonable blueprint for a bridge, and clearly present their findings to the class. Use the following three-point rubric to evaluate students' work during this lesson:

> Three points: Students worked well together in their groups, developed an exemplary plan for their bridge, drew an accurate blueprint that was labeled clearly and accurately, and made an interesting presentation to the class.
>
> Two points: Students worked somewhat well together in their groups, developed a reasonable plan for their bridge, drew a somewhat accurate blueprint that was labeled clearly and accurately, and were prepared for their presentation to the class.
>
> One point: Students had some difficulties working together in their groups, developed a partial plan for their bridge, drew a partial blueprint, and made a brief presentation to the class.

Extension:

To the Rescue!

When a structure collapses, federal, state, and local organizations rush to the aid of any victims. Brainstorm with the class which organizations help during a disaster. Ask them about the role of these organizations. Have students each become a "Disaster Action Kid," visit the Web site for kids set up by the Federal Emergency Management Agency: http://www.fema.gov/kids/

Suggested Readings:

Catastrophe! Great Engineering Failure - and Success
Fred Bortz, W.H. Freeman and Company, 1995.
Good engineers should try to anticipate anything that could go wrong with whatever it is they are designing. Most do, and some unfortunately do not. This book examines six cases where a mistake in design led to disaster. The fascinating details of each incident is described, illustrated in photographs and drawings, and analyzed so the reader can understand what went wrong and why.

Collapse: When Buildings Fall Down
Phillip Wearne, TV Books, 2000.
The author tells the stories of how eleven of the worst structural engineering disasters of the last fifty years occurred. The stories of these disasters are also the stories of the forensic engineers who sifted through layers of debris, studied architectural drawings, and staged reconstructions in order to search for the true cause of each catastrophe.

Web Links:

Great Engineering Failures: Tacoma Narrows Bridge
The collapse of the Tacoma Narrows Bridge is featured on this web page. The site will lead you to other great bridge disasters.
http://www.brad.ac.uk/acad/civeng/marketing/civeng/failure1.htm

Resonance
A multimedia demonstration showing that not only can resonance destroy a bridge, it can also reduce to rubble your family's favorite glassware and even disintegrate a kidney stone.
http://sciencejoywagon.com/physicszone/lesson/09waves/resonan/resonanc.htm

Structures
An elementary classroom for the budding civil engineer tells all about structures and what a civil engineer does for a living.
http://www.brad.ac.uk/acad/civeng/marketing/structures/

CONTEST: Welcome to the Bridge Building Home Page
The Illinois Institute of Technology invites you to participate in their annual basswood bridge building contest.
http://www.iit.edu/~hsbridge/database/search.cgi/:/public/index

Engineering Disasters: Learning from Failure
The engineering department at the State University of New York shares its list of websites on engineering disasters, from falling bridges to Chernobyl.
http://dol1.eng.sunysb.edu/disaster/

Vocabulary:

box girder bridge
Definition: A type of bridge made of steel or concrete that is constructed from supporting beams that look like a long box.
Context: Box girder bridges, such as the Melbourne Bridge in Australia, are popular because they are light, strong, and economical.

collapse
Definition: To break down or fall in.
Context: When the Silver Bridge collapsed in 1967, 37 cars and trucks fell into the river.

compression
Definition: A pressing force that squeezes a material so that it becomes more compact.
Context: The weight of the building on its lower columns caused a great deal of compression.

I-beam
Definition: A steel joist or girder with short flanges and a cross section formed like the letter "I."
Context: In 1967, a broken I-beam on the Silver Bridge in West Virginia caused the bridge to collapse.

tension
Definition: A stretching force that pulls on a material.
Context: The vertical cables of suspension bridges must remain in tension at all times because of the continuous weight of the roadway and cars.

torsion
Definition: the twisting and wrenching of a structure by the exertion of forces.
Context: In 1940, strong winds created too much torsion, causing the Tacoma-Narrows bridge to collapse.

unstable
Definition: Characteristic of a structure that collapses or deforms under a realistic load.
Context: The bridge was unstable and collapsed during the earthquake.

Academic standards:

Grade level:
6-8
Subject area:
Technology
Standard: Understands the nature and uses of different forms of technology.
Benchmark: Knows that construction design is influenced by factors such as building laws and codes, style, convenience, cost, climate, and function.

Grade level:
6-8
Subject area:
Technology
Standard: Understands the nature and uses of different forms of technology.
Benchmark: Knows that manufacturing processes use hand tools, human-operated machines, and automated machines to separate, form, combine, and condition natural and synthetic materials; these changes may be either physical or chemical.

Grade level:
6-8
Subject area:
Technology
Standard: Understands the nature of technological design.
Benchmark: Knows that the design process relies on different strategies (i.e., creative brainstorming to establish many design solutions, evaluating the feasibility of various solutions to choose a design, and troubleshooting the selected design.

Credit:
Jordan D. Brown, a freelance author in New York City, enjoys writing books, magazines, and Web sites for kids and teachers.

DiscoverySchool.com
http://www.discoveryschool.com

Name: ____________________

Designing a Bridge

I. Use the questions below to guide your research on factors to consider when designing a bridge.

1. What natural forces might affect your bridge? How can you compensate for them?

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2. Which materials are most suitable for your bridge? Why? Keep in mind wear and tear on the bridge, temperature, wind speed, and expense when making your decision.

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3. Which shapes are you using to support weight on your bridge? Why?

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II. Draw a blueprint of your bridge in the space below.

III. On the back, write a paragraph summarizing your reasoning for your bridge design choices.

Name: ____________________

Top 10 Construction Achievements of the 20th Century

In 1999, the architectural community recognized 10 structures as being the finest architectural achievements of the 20th century. The reasons for the selection were that the structures listed below provided a strong benefit for humanity, had measurable economic impact, were innovative in using new technology, and added value to the community in which the project was located.

Use library books or the Internet to learn more about one of the structures on this list. (A good source is the site: (http://192.215.32.157/conexpo/news20.asp) During your research, record important facts, such as location, size, date built, materials, and design features. Then find out how these structures are reinforced to protect against destructive forces such as high winds, floods, and earthquakes.

1. Chunnel Tunnel (links England with France)
2. Golden Gate Bridge
3. Dwight D. Eisenhower system of Interstate and Defense Highways
4. Empire State Building
5. Hoover/Boulder dam
6. Panama Canal
7. ydney Opera House
8. Aswan High Dam
9. World Trade Center
10. Hong Kong Airport

Structures Fact Sheet

Note to teachers: If your class does not have access to the Internet, students need to get the following information about structural design from you to complete the activity.

Information about Forces: Common Terms

The forces listed below act on large structures in the following ways:

1. Compression. A force that squeezes a material together. When a material is in compression, it tends to become shorter.

2. Tension. This force stretches a material apart. When a material is in tension, it tends to become longer.

3. Bending. Bending occurs when a straight material becomes curved, causing one side to squeeze together and the other side to stretch apart.

4. Shear. A force that causes parts of a material to slide past one another in opposite directions.

5. Torsion. A force that twists a material. Torsion of a structure is often caused by strong winds.

Properties of Different Materials
Below are the advantages and disadvantages of using different kinds of materials.

Wood.
Advantages: Cheap, lightweight, and moderately strong in compression and tension
Disadvantages: Rots, swells, and burns easily

Plastic.
Advantages: Flexible, lightweight, long-lasting, strong in compression and tension
Disadvantages: Expensive

Aluminum.
Advantages: Lightweight, doesn’t rust, strong in compression and tension
Disadvantages: Expensive

Brick.
Advantages: Cheap, strong in compression
Disadvantages: Heavy, weak in tension

Continued

Structures Fact Sheet

Concrete.
Advantages: Cheap, fireproof, weatherproof, molds to any shape, strong in compression
Disadvantages: Cracks with temperature changes, weak in tension

Reinforced concrete.
Advantages: Cheap, fireproof, weatherproof, molds to any shape, strong in compression and tension
Disadvantages: Can crack as it cools and hardens

Iron.
Advantages: Molds to any shape, strong in compression
Disadvantages: Weaker than steel in tension, breaks without warning

Steel.
Advantages: Very strong in compression and tension
Disadvantages: Rusts, loses strength in extremely high temperatures

How Shape Affects Structures

The shape affects the strength of a structure. The most common shapes used in construction are triangles, rectangles, and arches. Below is a brief description of the effect of weight on each shape. To illustrate how the same heavy weight affects different shapes, imagine how the weight of elephants would affect a rectangle, a triangle, and an arch that are about the same size.

Rectangles. One elephant would push down on a rectangle and cause the top side to bend; rectangles cannot handle the weight of three elephants.

Triangles. The weight of one elephant causes the top two sides to squeeze together and the bottom side to pull apart. Triangles can handle as much weight as six elephants; this shape is very sturdy.

Arches. The weight of one elephant presses down on the arch and is spread outward along the curve to the ground below. The arch can handle the weight of three elephants but no more.